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# Relationship Between Canopy Location and Tensile Strength of Leaves of Heteromeles arbutifolia in Malibu, CA

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# Relationship Between Canopy Location and Tensile Strength of Leaves of *Heteromeles arbutifolia* in Malibu, CA

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## Abstract

Our hypothesis is that canopy location has an effect on the characteristic tensile strength of leaves, with the leaves on the top of the canopy having greater strength than the leaves on the bottom. We tested our experiment by sampling leaves from the top and bottom of three *H. arbutifolia* specimens, obtaining raw measurements of size, and testing the tensile strength of each leaf using the Instron. We performed t-tests on the data to determine if the average length, width, thickness, and tensile strength were statistically different depending on if our p values were $< 0.05$ when top and bottom leaves of the same tree were compared. We chose a chapparral stand removed from heavy human traffic and influence, eliminating as many extraneous variables as possible by taking leaves from the same tree of the same age from the same position on the branch and chose three trial specimen of similar height in the same area to reduce the possibility of varying sunlight exposure or water supply from affecting leaf morphology in a way that canopy position would not. The results show that blade length between top and bottom is statistically significantly different, while blade thickness and lateral strength at midsection were not statistically different. From our analysis of the data, it is clear that leaves on the bottom of the plant were longer and broader than leaves on the top, but we determined that canopy location does not have a major effect on tensile strength or thickness, supporting a null hypothesis.

## Introduction

It has been found that leaves exposed to sun and shade have unique morphological adaptations due to factors such as photosynthetic efficiency (Givnish 1988). With this in consideration, we speculated about whether these modifications would lead to a difference in tensile strength. In further refining our idea, we chose to see if this concept was applicable to leaves on the same plant. We chose to study the native chaparral *Heteromeles arbutifolia*, which would enable our findings to have an impact at the local level as well as be extrapolated to areas around the world that share the same Mediterranean-type climate. A better understanding of the distinctive alterations within a single plant assists in knowing how this plant will respond in times of stress—most notable is the summertime, when plants are subjected to water and heat stress (Nahal 1981). Findings show that leaves in the shade are adapted to have greater chloroplast and stomatal size in addition to having an increased thylakoid to grana ratio (Givnish 1988). Further, the venation of shade leaves has been shown to have a higher hydraulic resistance than leaves in the sun (Nardini et al. 2005). Due to this difference in structural make-up, we hypothesized that leaves gathered from the bottom of the plant ("shade" leaves) would have greater tensile strength than those collected from the canopy ("sun" leaves). To conduct experimental testing, we sought to gather 24 leaves (12 top, 12 bottom) from three individual *H. arbutifolia* plants located in the same stand on Pepperdine campus. Utilizing the Instron, we planned to then amass data on the mechanical strength of our samples and statistically analyze our findings to determine if a difference existed between leaves collected from the top and bottom.

## Study Site

Specimens were collected from an isolated chaparral stand on Pepperdine Campus and data were collected in the Botany laboratory of Pepperdine University in Malibu, California in April of 2014.

## Materials and Methods

**Figure 1.** (left and below) Twelve leaf samples were each taken from the top and bottom of 3 different H. arbutifolia plants using hand clippers.

**Figure 2.** (Below) Leaf specimens were tested for tensile strength using the Instron machine in the Natural Science laboratory .

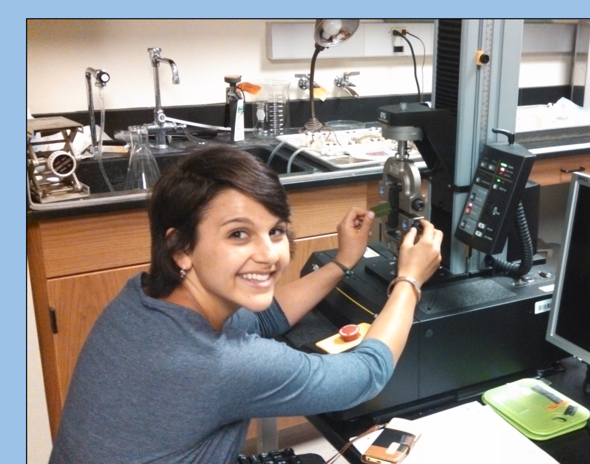


**Figure 3.** (Above) Digital calipers were used to determine thickness to the nearest mm at midrib, tip, and edge and then averages were taken.

**Figure 4.** (Above) Leaves were cut systematically into 25mm x 45mm sections along the midrib using razors and stencils.

We identified H. arbutifolia as the species for investigation and sampled 12 leaves from the topmost branch and the bottommost branch of three specimens of approximately the same height, taking the sixth youngest leaf from the tip of each branch. The leaves were collected at approximately 3 o'clock in the afternoon in a chapparal stand on a steep hill across from the Soccer fields on Pepperdine University's campus. The thickness, length, and tensile strength (lateral strength at midsection) of each leaf were tested using digital calipers, a metric ruler, and the Instron machine.

## Results

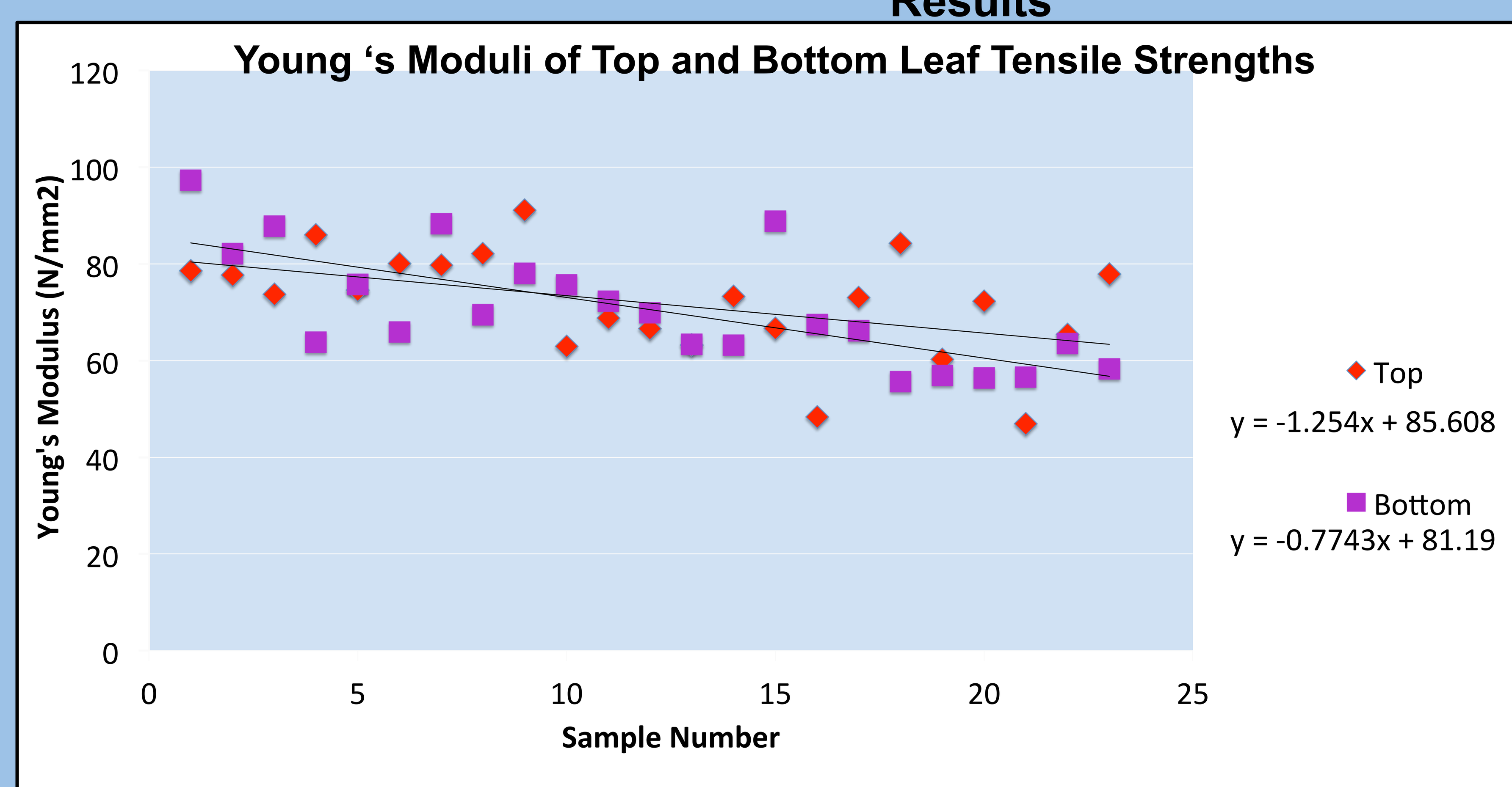



**Figure 5**: Figure 5 shows a scatter plot of the data collected from the Instron machine, displaying the Young's modulus of each leaf as a function of position. The similar slopes of the best fit lines as well as the statistical analysis of paired t-tests that show that t=0.3466 and p=.7304, therefore the top and bottom tensile strengths are not significantly different.

**Figure 6**: Bar graph shows that for the Top vs. Bottom Mean Blade thickness t-test, p=. 0938, therefore it is not significantl y different.

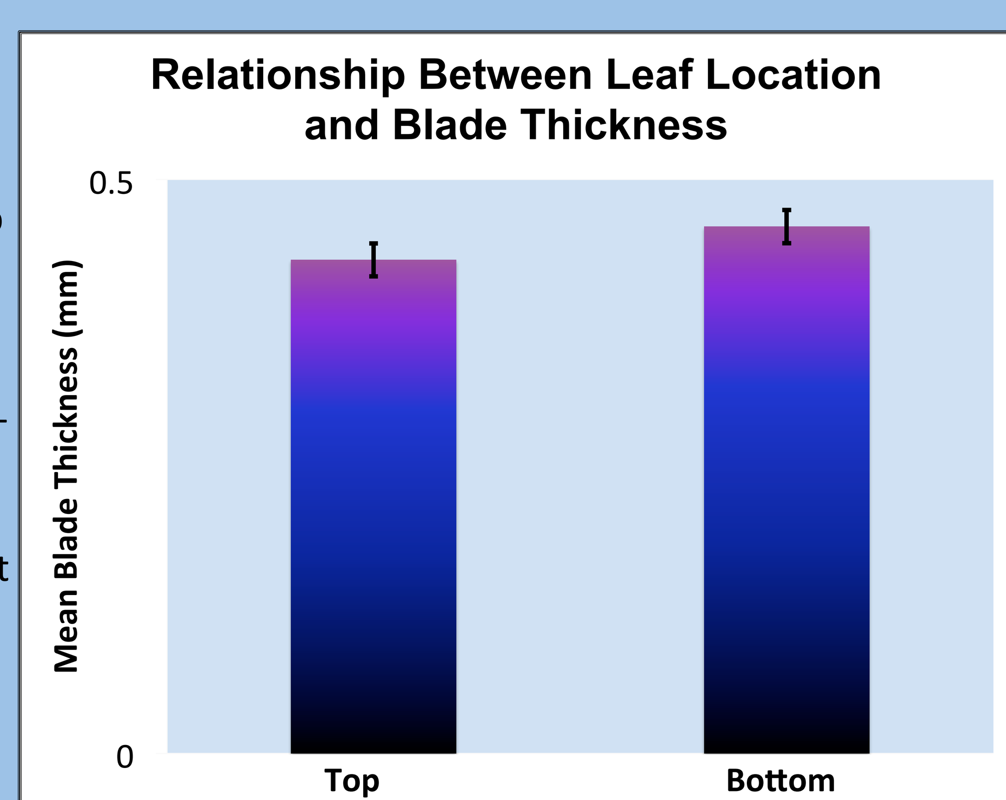
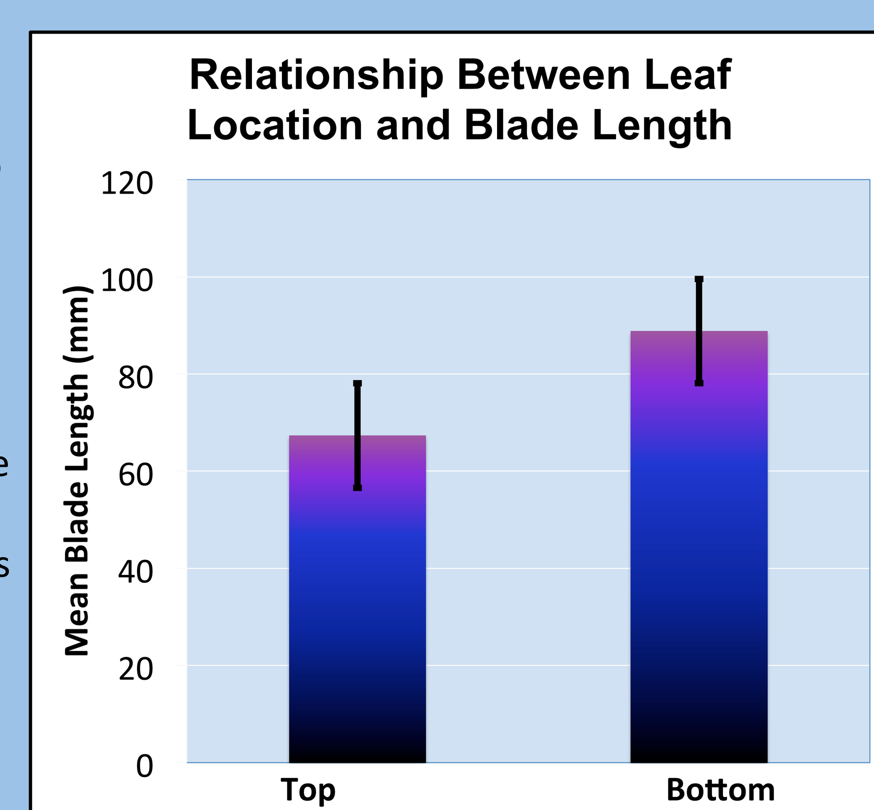



**Figure 7:** Bar graph shows that for the Top vs. Bottom Mean Blade length t-test, t=8.5224 and p<.0001, therefore, blade length for bottom leaves is significantly longer than for top leaves.




## Discussion

We hypothesized that the leaves at the bottom of a canopy would have higher tensile strength than those at the top of the canopy. After testing the tensile strength of leaves from the top and bottom of three plants of *Heteromeles Arbutifolia* we discovered several things. First, the Young's Modulus of elasticity showed no significant difference between the leaves from the top and bottom. The Young's Modulus measures the ratio of stress to strain on the leaf. The fact that there was no significant difference says that the leaves of the top and bottom performed relatively the same in terms of tensile strength. Therefore our null hypothesis was accepted. We hypothesized that the bottom leaves would have a higher tensile strength because the leaves at the bottom of the canopy seem to undergo more stress. There are usually in the dark and not exposed to very much light and they also are more subject to the stress due to animals disrupting the vegetation. We did find a significant difference between the mean blade lengths of the leaves. The leaves at the bottom of the canopy had a mean length of 88.8mm while the leaves at the top of the canopy had a mean length of 67.3mm. This was interesting because of the relationship and differences between sun and shade leaves. One study found that small thick leaves were associated with sun leaves while large thin leaves were associated with shade leaves (Nardini et al. 2005). Although we found no significant difference in the average thickness of our leaves, these results make sense because shade leaves are not exposed to much light and therefore need a wide surface to capture light and need to be thin to let light to flow through then to the other leaves underneath. Literature by Shujie Wang identified that the strength of leaves is ultimately related to the material composition of the structure. More lignin and cellulose in a leaf contributes to higher surface hardness (Wang 2012). Based on this information, the leaves of the top and bottom of the canopy most likely did not have significantly different tensile strengths because they are the same species and are made of the same material—equal amounts of lignin and cellulose. Furthermore, the sclerophyllous leaves of *H. Arbuitifolia* are adapted to dehydration and show on a cellular level an overall interconnected or net-like appearance (Balsamo et al. 2003). So the plant as a whole is adapted to be durable and therefore the tensile strength of top leaves is not significantly greater than that of the bottom leaves.

## Conclusions

Our findings lead us to conclude that:
- Bottom leaves have greater blade length than top leaves
- Bottom leaves are better adapted to shadier environments with increased leaf length and size.
- Canopy location does not have a significant effect on the thickness or tensile strength of *H. arbutifolia* leaves

It is possible that further observation and experimentation may support a definite relationship between leaf canopy position and water status.

## Literature Cited

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